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History, Processing, and Usage of Recycled Glycol for Aircraft Deicing and Anti-Icing

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16. Abstract

Numerous advancements in aircraft deicing/anti-icing fluids, application methodologies, training, and deicing/anti-icing equipment have emerged in recent years; however, the undesirable effects of deicing fluid runoff on the environment remain a challenge. Although most proper disposal operations includes precise metering on the resultant deicing operation runoff into sewer systems in amounts deemed not ecologically detrimental, this practice is not considered a suitable solution by all. Costs associated with glycol runoff may provide additional incentive for recycling. Capturing spent glycols for recycling into aircraft usable, certified deicing/anti-icing products or marketable glycols for nonaviation use is anticipated to ease the stress of local environs and water treatment plants. Practices and procedures addressing the recycling and reuse of these glycols are the underlying focus of this investigation.

The primary objective of this study was to globally investigate and document spent glycol recycling methods and practices, including Asian, former Soviet bloc countries, and other areas of the world not within the purview of current SAE/ISO fluid standards.

As a minimum a combination of 140 worldwide airports, airlines, air carriers, recovery vehicles suppliers, recycling equipment vendors, recycling equipment operators, and vendors of equipment used for diversion and containment of spent aircraft deicing fluid (ADF) were sent questionnaires. Technical and economic information was collected from questionnaires, vendor literature, government reports, communication via facsimiles, internet e-mailings, phone conferences, on-site meetings, and the experience of the author.

Study results provide information associated with establishing an on-site or remote glycol recycling facility, what can be expected from such a facility, utilization of the refined glycol, and a method for reprocessing into aircraft deicing/anti-icing fluid.

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LIST OF ABBREVIATIONS

ADF	Aircraft Deicing Fluid
AEA	Association of European Airlines
AMS	Aerospace Material Standard
AMS 1424	Titled: Aircraft Deicing/Anti-Icing Fluid, Type I
AMS 1427	Titled: Aircraft Deicing/Anti-Icing Fluid, Propylene Glycol Base
AMS 1428	Titled: Aircraft Deicing/Anti-Icing Fluid, Type II, III, IV
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
ISO	International Standards Organization
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly Owned Treatment Works
SAE	Society of Automotive Engineers

EXECUTIVE SUMMARY

In the United States, beginning in 1991, there have been tremendous advancements in the aircraft ground deicing state of the art, such as the development of deicing and anti-icing fluids, fluid certification standards, improved fluid application methods, advanced de/anti-icing equipment, and emerging technologies in the area of ground and onboard ice detecting equipment. However, these advancements have not eliminated the potential negative effects of spent glycol on the environment.

The Phase I Storm Water Discharge Permit regulations specifically cover the direct discharge of aircraft deicing and anti-icing fluid (ADF) contaminated storm water from airports in the nation's surface waters. Although these regulations were developed by the Environmental Protection Agency (EPA), they are implemented, in most cases, by individual states. When developing individual airport storm water discharge permits, states may take into account local water quality issues.

These impacts have developed a need for some airports and airlines to initiate various methods to recover and recycle the spent ADF, and provided the impetus for the Federal Aviation Administration's William J. Hughes Technical Center to support a study on the "History, Processing and Usage of Recycled Glycol for Aircraft Deicing and Anti-Icing."

The primary objective of this study is to investigate and document spent glycol recycling methods and practices, including Asian, former Soviet bloc countries, and other areas of the world not within the purview of current SAE/ISO fluid standards.

As a minimum a combination of 140 worldwide airports, airlines, air carriers, recovery vehicles suppliers, recycling equipment vendors, recycling equipment operators, and vendors of equipment used for diversion and containment of spent ADF were sent questionnaires. Technical and economic information was collected from questionnaires, vendor literature, government reports, communication via facsimiles, internet e-mailings and phone conferences, on-site meetings, and the experience of the author, and incorporated into this report.

It is anticipated that the report resultant of this study will provide key information associated with establishing an on-site or remote glycol recycling facility, what to expect from such a facility, utilizing the refined glycol or reprocessing into aircraft deicing/anti-icing fluid, and representative costs as compared to traditional glycol disposal.

1. INTRODUCTION.

1.1 PURPOSE.

This investigation has been conducted in response to a request from the Federal Aviation Administration's (FAA) William J. Hughes Technical Center.

The primary objective of this contractual effort was to investigate and document spent glycol recycling methods and practices conducted worldwide.

1.2 BACKGROUND.

The use of aircraft deicing/anti-icing glycol based fluids is thought to have originated in Europe, with the European and Scandinavian recovery and recycling processes originating in about 1986. Before the advent of SAE standards established in 1990, there were Association of European Airline (AEA) standards for aircraft deicing and anti-icing fluids. Some airports outside North America recovered spent ADF and performed recycling and reprocessing of the glycol into an AEA Type I aircraft deicing/anti-icing fluid. It was unclear if these recycled products were certified to any known international standard at that time.

In the US, airlines first used traditional North American deicing fluids, which were soon replaced by the newly developed SAE Type I aircraft deicing fluids and Type II anti-icing fluids. Improvements to fluid technology eventually resulted in Type IV anti-icing fluid. With the advent of Type IV fluids, their use became more popular than Type II in North America due primarily to better holdover time (HOT) characteristics. Type II fluids continue to be used in much of Europe. These were all chemically sophisticated fluids with a cost per gallon being substantially more than the traditional North American deicing fluids used in the 1980s. The U.S. airlines investigated the application techniques used by the Europeans to reduce excessive usage of these new fluids. With the implementation by the Environmental Protection Agency (EPA) of the Phase I Storm Water Discharge regulations in 1990, airports and airlines became very concerned about disposal of spent ADF wastewater and the associated costs.

Although proper disposal still includes precise metering of the resultant deicing operation run-off into sewer systems in amounts deemed not ecologically detrimental, this practice is not considered a suitable solution by all. Uncontrolled runoff of glycol products in the environment is considered one of the least acceptable method. Some authorities and/or airports may levy fees or fines for excessive runoff. Costs associated with glycol runoff, such as additional fees and possible fines and the maintenance and monitoring of equipment for metering into sewer systems, may provide the additional incentive for recycling. The capture of spent ADF for recycling into aircraft usable, certified Type I deicing/anti-icing fluid or marketable glycols for nonaviation use, is anticipated to ease the stress on local environs and water treatment facilities.

1.3 RELATED DOCUMENTS.

The EPA document titled "Preliminary Data Summary-Airport Deicing Operations,"[1] relates directly to some of the issues addressed herein and has been included in parts of this study.

2. DATA COLLECTION.

Data was collected from airports, airlines, and vendors located in the U.S., the European continent including the Scandinavian countries, Great Britain, Russia, Poland, and the Asian countries of Japan, Korea, and China. The EPA's Preliminary Data Summary Report on Airport Deicing Operations was also referenced for it's information on recycling locations and the text on recovery vehicles and recycling vendors in the US.

2.1 QUESTIONNAIRES.

The initial data collection effort was to acquire information regarding the worldwide locations that were performing or had performed either the recovery of spent ADF or both the recovery and recycling of this fluid. Questionnaires were developed and sent to these airport locations, domestic and foreign airlines, and vendors throughout the world that were involved in the recovery and recycling of spent ADF. Response to the inquires were conducted by facsimile, e-mail and phone conferences. The number is of inquiries totaled a minimum combination of 140 airports, airlines, and vendors.

2.1.1 Airport Questionnaire.

The initial inquiries were sent to the domestic, international and foreign government and airline associations, including: Civil Aviation Authority-Norway and Sweden, Association of European Airlines, Airport Council International—Europe, Transport Canada, Air Transportation Association, U.S. Air Force and the Norwegian Air Traffic and Airport Management Association. The results resulted in identifying the airports that were involved in recovery and/or recycling. For the Asian countries, each airline had to be contacted individually to determine if any type of this activity was taking place.

From the results compiled from the initial inquiry a more specific airport questionnaire was developed and sent. The airport questionnaire requested if the facility is or was involved in any type of activity regarding the recovery and/or recycling of spent ADF, the details of the recovery and recycling process. Also requested was the name and phone number of the company performing these activities. Usually, the airport was directly involved with this activity and the referral generally pertained to either the major airline at that airport or to the vendor that was contracted to perform the task. A follow-up phone conference would normally follow to determine if the questionnaire needed to be sent with translation in the language of the country. The translation was completed in several instances.

2.1.2 Airline Questionnaire.

The airline questionnaire requested if the airline was knowledgeable about the airports where recovery and recycling was being performed and details about recovery techniques at the gates and deicing pads. The method of data collection was especially beneficial for determining the activity in Russia, Poland, Japan, Korea, and China.

2.1.3 Vendor Questionnaire.

The vendors contacted were manufacturers of recovery vehicles, recovery drain equipment and fluid diversion systems. Also contacted were the manufacturers of recycling equipment and operators of the recycling facilities at the airports. Translation programs were also needed to communicate effectively with some foreign countries.

2.2 SITE VISITS, MEETINGS, AND PHONE CONFERENCES.

During this investigation six site visits were conducted at both U.S. and European airports to observe various methods of spent ADF recovery, glycol wastewater retention, and to discuss the economic benefits of various wastewater treatment and recycling systems. Phone conferences were conducted almost daily to clarify the response to most of the questionnaires.

3. REQUIREMENTS.

There are thirteen categories addressed in this section. The data collected and documented was delineated under each category. This effort includes ADF collection, recycling, and the utilization of the collected glycol runoff. Metering of spent ADF into sewer systems, for the purpose of this study, is not considered unique or environmentally friendly and consequently out of the scope, except for associated cost information, when applicable. Likewise, the use of low glycol or no glycol decing/anti-icing methods is considered out of the scope of this study.

1. Document the history and related events leading up to the feasibility of the collection and reprocessing of aircraft deicing/anti-icing glycol runoff into useable, certifiable glycol deicing/anti-icing fluids, including selected areas of the world which do not conform to current SAE/ISO specifications.

   Deicing involves the removal of frost, snow, or ice from aircraft surfaces or from paved areas including runways, taxiways, and gate areas. Anti-icing refers to the prevention of the accumulation of frost, snow, or ice on these same surfaces. For the purpose of this report, the deicing fluid (Type I) and anti-icing fluids (Type II and IV) that are runoff from the aircraft will be called ADF.

   Deicing/anti-icing operations are typically performed from October through May at many airports throughout the world. Low Dissolved Oxygen (DO) levels are less likely to occur during the coldest period of the deicing season because of the higher solubility of oxygen in water at lower temperatures and lower biological activity. As the season ends and the temperature rises, airports are still conducting deicing operations, and the snow dump piles containing deicing agents begin to melt, releasing chemicals into receiving streams. Also, biodegradation of deicing chemicals is beginning to increase, enhancing the likelihood of reduced DO in receiving streams.

   In the U.S., the EPA Report [1] estimated that prior to the implementation of Phase I Storm Water Discharge Permit regulations (pre-1990) the airline industry discharged approximately 28 millions gallons (50% concentration) of ADF annually to surface waters. EPA now estimates that, due to best management practices put into place under the storm water permit regulations, current discharges are 21 million gallons of ADF (50% concentrate) per year to surface waters with an additional 2 million gallons discharged to Publicly Owned Treatment Works (POTWs). EPA also estimates that this will be further reduced to less than 17 million gallons of ADF (50% concentration) per year discharged to surface waters when the requirements of all airport storm water permits are fully implemented. The volume discharged to POTWs is expected to steadily increase.

Finally, EPA estimated possible reductions in discharges of ADF if effluent limitation guidelines and standards were implemented for airport deicing operations. Assuming that all airports with potentially significant deicing operations could achieve a 70% collection efficiency of ADF applied, EPA estimates that discharges to surface waters from airport deicing operations could be reduced to approximately 4 million gallons ADF (50% concentration) per year. This would likely result in greatly increased volumes to POTWs, as well as an increase in the use of source reduction technologies, recovery and recycling, and treatment systems.

In Europe and in the Scandinavian countries, the historical events that evolved for airports involved with recovery and recycling of spent ADF were:

- In 1986, at the Lulea Airport in Lulea, Sweden, spent ADF was recovered and recycled into ADF at the airport. The start-up and operation of this facility was performed by Peter Mattsson. At that time aircraft deicing fluids did not require certification, the airlines would perform freeze point checks and inspect the recycling facility. For the 1987-88 winter season, corrosion tests were added as a requirement using SAE Deicing Fluid Specification AMS 1427. Then beginning with the 1990-91 season, deicing fluid had to be aerodynamically tested in accordance with the AEA guidelines. In the years following, the reprocessed ADF was required to meet the SAE AMS 1424. Spent ADF was also collected at Umea, Sundsvall, Skelleftea and Kiruna, and Sweden, then trucked to Lulea for recycling into ADF. Currently, the recycling facility is not operational due to a specification conflict with SAE AMS 1424C.

- In the 1980s, at the Charles de Gaulle Airport in Paris, France, spent ADF was recovered from under the gantry deicing structures and transported to the on-airport recycling plant. The recycling facility had operated during the 1999/2000 winter season with the airport dispensing Type I fluid. Currently, the recycling facility is not in operation due to the product conflict with SAE AMS 1424C specification.

- In 1990, at the Fornebu Airport in Oslo, Norway, spent ADF was recovered and recycled into Type I aircraft deicing/anti-icing fluid at the airport. This recycling facility at Fornebu is still operating, even though the Fornebu Airport was replaced by the Oslo Gardermoen Airport in Oslo, Norway in 1998. Spent ADF is being collected at Gardermoen, then transported by truck to Fornebu for recycling. The airport was using the recycled Type I fluid during the 1999/2000 winter season. Currently the recycled product is stored pending the resolution of the conflict with SAE AMS 1424C.

- In 1991, operators at the O'Hare International Airport (ORD), Chicago, IL, was the first U.S. attempt on record to recover and recycle aircraft deicing fluid. American Airlines, under the direction of Max Kurowski, established a pilot program for the City of Chicago to purchase recycled deicer fluid for runway deicing. This recycled fluid was reprocessed from spent ADF that had been recovered from the American Airlines gate areas. The spent ADF was collected by vacuum vehicles then trucked off-airport to be recycled and processed into the runway deicing fluid. In that same year American Airlines established another pilot program in which the aircraft deicing fluid recovered from the ORD gate areas was reprocessed into automotive antifreeze.

- In 1993, at the Munich International Airport in Munich, Germany, (see appendix A) an on-airport recycling facility was constructed, and spent ADF was recovered and recycled into ADF Type I. The events that led up to the feasibility of this facility are as follows. In 1992 the airport opened with one main issue which was that the airport is located in an area of high level ground water. The designation order and the approval by aviation law for new airports stated "The deicing procedures may not effect ground water and any other water within the airport area and may not harm the sewage plant…the approval of all deicing fluid has to be given by official authorities…unless the deicing fluids and procedures are not approved, only nonchemical deicing procedures are allowed or flight operation has to be ceased." These injunctions include both ground and aircraft deicing. For example, during the winter season which lasts from October till the end of April, all water on the apron is collected, buffered in large basins, and transported to the sewage treatment plant. Due to the high oxygen demand of spent ADF, a very large investment to increase the capacity of the existing sewage treatment plant would have been necessary. To avoid this, the Munich Airport and Lufthansa established a task force to determine a solution to solve the problem, it was to "Recycle the used aircraft deicing fluid on the airport and use it again for aircraft deicing." The recycling facility is operated by Clariant Gmbh (a deicing and anti-icing fluid manufacturer) and owned by the Munich Airport and GlobeGround. This appears to be the only on-airport recycling facility that is reprocessing spent fluid into an SAE AMS Type I fluid that meets the current SAE AMS 1424C. A separate report titled "Recycling of Aircraft De- and Anti-icing Fluid, The Munich Way" is part of this requirement.

- In 1994, at the Stapleton International Airport in Denver, CO, Continental Airlines operated a deicing pad where ADF runoff was collected by drains into collection tanks and then recycled off-airport into concentrations of industrial grade glycol. During that period the new Denver International Airport engineering department commissioned a "comprehensive alternatives study" for dealing with deicing fluids at this new airport. The study concluded that a separate wastewater treatment plant for the new airport was not feasible, since the operating costs for a small plant were virtually the same as for a big plant. In 1995 the new Denver International Airport (DIA) was opened to replace Stapleton with a recycling facility owned by the Denver International Airport and Aircraft

Deicing Systems Incorporated (ADSI). ADSI was the operator of the recycling facility and also for the storage and distribution systems for the SAE AMS Type I fluid and Type IV fluid used by airlines. The recycled glycol is being sold as industrial grade glycol.

- Interest in recovery of spent ADF has increased, on-site and off-site recycling of ADF-contaminated wastewater is being performed or is being considered at several airports including:

  U.S. AIRPORTS

  (ALB) Albany County
  (BDL) Bradley International
  (DCA) Washington-Dulles
  (DTW) Detroit Municipal
  (EWR) Newark International
  (IAD) Washington National
  (MKE) Mitchell International
  (MSP) Minneapolis-St. Paul International
  (ORD) O'Hare International
  (PIT) Greater Pittsburgh International
  (PVD) T.F. Green
  (SLC) Salt Lake City

  CANADIAN AIRPORTS

  (YHZ) Halifax International
  (YOW) Ottawa-MacDonald-Cartier International
  (YQB) Quebec City
  (YQT) Thunder Bay
  (YUL) Montreal International
  (YVR) Vancouver International
  (YYZ) Toronto-Lester B. Pearson International

  EUROPEAN and SCANDANAVIAN AIRPORTS

  (CDG) Charles de Gaul International
  (MUC) Franz Josef Strauss International
  (OSL) Oslo Gardermoen
  (LLA) Lulea-Kallax
  (XXX) Fornebu

  FORMER SOVIET BLOC AIRPORTS

  Unknown

  ASIAN AIRPORTS

  Unknown

2. Document, in general terms, the equipment and means employed for spent glycol collection, storage, and transportation to a remote reprocessing facility, or if the reprocessing facility can be located on airport property and space associated for same.

Airports use a variety of recovery and collection equipment, including:

- gate and ramp area drainage collections systems
- storm sewer inserts
- designated aircraft deicing pads
- temporary aircraft deicing pads
- electrically operated storm drain valves
- manually operated storm drain valves
- glycol recovery vehicles

A typical collection system consists of graded concrete pavement with trench or square drains connected to a wastewater storage facility via a diversion box. The diversion box allows uncontaminated storm water to be diverted to storm water outfalls. At Munich Airport the spent ADF is first delivered by pipeline to an underground collection system. The collected fluid is first discharged into a tank where the glycol concentration is measured with a densiometer. The system continuously monitors all ADF runoff that comes from the deicing pads. Fluid with more than 5% glycol concentration is pumped to an underground basin for truck transportation to the recycling plant. Concentrations lower than 5% are pumped into the storm water basin and then metered to the local sewage plant. This fluid is diverted with the use of electrically operated storm drain valves. It is possible to easily change the 5% switch-level but this percentage was decided based on the transportation costs and the ability of the local sewage plant to accept the quantity of wastewater. The collected spent ADF is then transferred to on-airport storage tanks, detention ponds, or underground concrete containment basins via pipeline or by tanker trucks. If the recycling facility is off-airport, the wastewater is transported either by tanker truck or by rail car. If the recycling facility is on-airport, the wastewater is transported by pipeline or by tanker truck. Individual airports or airlines often rely on a combination of these collection strategies, varying the collection method to suit their deicing area configurations.

Depending on the production capacity of the recycling plant relative to the size of the airport, a general footprint needed for an on-airport plant would be approximately one-quarter acre. With regard to the amount of storage needed for spent ADF, using the Denver Airport facility as a guideline, the storage for spent ADF is 1,260,000 gallons with 80,000 gallons of storage for the recycled glycol.

Storm drain inserts are used to close storm drains and prevent spent ADF contaminated wastewater from entering storm water drainage systems. An insert manufactured by AD Plus as a Catchbasin Insert is a patented removable valve system that captures fluid above the storm water drainage system, allowing very high concentrations of fluid to be recovered while preventing fluid from contaminating storm water lines. Valves are closed prior to deicing and opened after event cleanup to allow precipitation to pass to storm water piping when deicing fluid is not applied. The valve and transition plate are removed in less than five minutes to accommodate high summer storm water flows and/or to allow manhole access for cleaning and inspection. In addition to the storm drain insert, AR Plus manufactures the Model 2800 Interceptor which is a fully automated, intelligent airport storm water pumping system station capable of detecting glycol concentrations from 50% to 1% every second. It automatically directs storm water to predetermined outlets to facilitate recycling and/or processing for compliant discharge, which typically eliminates high cost of manpower and is available in diesel power for remote applications and electric power for fixed sites.

Temporary aircraft deicing pads are designed specifically for collecting ADF runoff generated during the deicing/anti-icing of a single aircraft. Their construction is of reinforced rubber or polypropylene mats and some have inflatable or foam berms to contain the contaminated wastewater and can be located on taxiways near the departure runway. The cost of these temporary pads are less than for permanent concrete pads with drainage and storage. Currently the names of these temporary pads include: Latimat, Ro-Mat, Pure Mat, Remote Aircraft Wash Platform, and Portable Evacuation System.

a. Glycol Recovery Vehicles

These types of vehicles are now used at several airports throughout the world. They provide a alternate method to collect spent ADF from the pavement where trench drains are not permitted to accept the ADF contaminated wastewater. This investigation found that they are used at airports in Korea, the Scandinavian and European countries, the United States, and Canada. In the U.S. Air Force reports listed in section 5, the Air Force also states that it uses the glycol recovery vehicles and some of the other collection equipment referenced in this section.

These machines vary in size depending on the ramp and gate areas that need to be serviced and the pavement must be plowed of snow prior to use. The snow considerably lowers the efficiency of these vehicles and also dilutes the ADF contaminated wastewater. Typically these vehicles are also used to collect fluids and debris during the nondeicing season. Some manufacturers of glycol recovery vehicles include: Vactor (Federal Signal), FRIMOKAR AG, Tenant, Tymco, and AR Plus/VQuip. General details of these glycol recovery vehicles are as follows.

- Vactor Manufacturing (Division of Federal Signal Corp.) Vactor Manufacturing, located in Streator, Illinois manufactures the Glycol Recovery Vehicle (GRV) designed with an 96-inch-wide rear-mounted vacuum pickup head. Materials are separated from the airstream in the main tank (1,800 US gallons) and in the high efficiency separators. The collected fluids are recirculated to prevent freezing between discharge cycles. An optional feature is a front mounted spray bar that dispenses a heated emulsifying liquid unto the pavement to break the glycol adhesion from the pavement. The vehicle's rear dump body design is equipped with a high flow pump system that facilitates the unloading of a collected glycol. GRVs are known to be employed at Detroit's Metropolitan Airport, Baltimore/Washington's International Airport, Toronto's L. B.

Pearson International Airport, Portland's International Airport, Dulles International Airport, Ronald Reagan Washington National Airport, Minneapolis-St. Paul International Airport, Milwaukee's General Mitchell International Airport, Albany's County Airport and Cincinnati/Northern Kentucky's International Airport.

- Tennant—Tennant, located in Minneapolis, Minnesota, has two models similar in design, the smaller model has a collection capacity of 120 U.S. gallons, while the larger model has a collection capacity of 510 gallons. Dual high-speed brushes scrub off stains, spills, and dirt while picking up debris at the same time. Each model includes an Optional Solution Recovery System which allows the operator to scrub for longer periods of time and has a vacuum wand attachment with a cleaning path of 50 inches. These scrubbers are effectively used in all size airports and at the Department of Defense aviation bases. Locations that are using the Tennant technology include: Chicago's O'Hare International Airport, Dallas/Ft.Worth's DFW International Airport, Reno's Airport, Tinker AFB, and Woodby Island Naval Air Station.

- FRIMOKAR AG—FRIMOKAR, located in Switzerland, manufactures several cleaning machines for airport use. The model specially designed for collecting ADF in the winter and FOD in the summer has a capacity has a collection capacity of 2245 U.S. gallons and a water tank volume of 686 U.S. gallons. It has a 118-inch sweeper brush for summer use with a 118-inch suction unit before the brush and a rear suction unit with a washing bar for direct suction after washing. It also includes a 98-inch scraper to remove sticky snow or debris. The machine has a specially designed hydrostatic transmission which allows the possibility of optimal working speed and can operate in temperatures down to -13°F. These FRIMOKAR machines are located at several airports in Scandinavia, including Oslo-Gardemoen, Stockholm-Arlanda, Helsifors-Vanda, Kiruna, and at several bases for the Finnish Air Force. Some of the European airports that have these machines are located in Munich, Vienna, Hamburg, and Zurich.

- AR Plus/Vquip—VQuip Inc., located in Burlington, Ontario, Canada, manufactures three vehicles specially designed for the spent ADF collection. These include:

  - T500 RampRanger—Deicing fluid collection unit, towable by airport tractors, tugs, or trucks, designed for very constricted gate cleaning and small airports. Fully automated operation with handheld control and powered by 20 hp diesel engine. Vacuum head collection width is 7′6″ with a maximum collection rate of 200 USG per minute. Usable capacity of the standard unit is 500 USG with an available optional capacity of 750 USG.

  - T1800 RampRanger—Intermediate 1800 USG capacity deicing fluid collection unit, towed by airport tractors at mid-size airports. Fully automated operation with in-cab controls powered by the tractor power takeoff shaft. Vacuum head collection width is 8′6″ with a maximum collection rate of 1,500 USG per minute using a combination of run dry submersible pumps and vacuum. Continuous in tank circulation solves the issues of sand and slush buildup in the tank during severe events. Discharge capacity is 1,500 USG through a quick connect 6″ fitting.

- T4000 RampRanger—Large 4000 USG capacity de-icing fluid collection unit, towed by specialized JCB 3185 tractors at larger airports. Fully automated operation with in-cab controls, powered by the tractor power take off shaft. Vacuum head collection width is 10′ with a maximum collection rate of 1,500 USG per minute using a combination of run dry submersible pumps and vacuum. Continuous, in tank circulation solves the issues of sand and slush buildup in the tank during severe events. Discharge capacity is 1,500 USG through a quick connect 6″ fitting.

These vehicles are known to be located at Chicago's O'Hare International Airport, Bradley International Airport, Newark's International Airport, Providence's T.F. Green Airport, Hamilton International Airport, Trenton's Canadian Forces Base, Toronto's L. B. Pearson International Airport, Dulles International and Ronald Reagan National Airports, US Air Force – Ellsworth SD, Buffalo's International Airport, TORP Airport, Norway, and Winnipeg International Airport.

- Tymco—Tymco, located in Waco, Texas, manufactures the HSP Regenerative Air Runway Sweeper. It's designed with an 97 inch wide pick-up head. The powerful blower on the HSP pulls air from inside the hopper, then blasts it down and across the pick-up head onto the pavement, forcing objects as heavy as bolts and particles as small as 10 microns into the hopper. The collection tank is 700 gallons.

  These vehicles are known to be located at Greater Cincinnati Airport and Kenton County Airport in Ohio, Austin's Robert Mueller Municipal Airport, Sante Fe Airport, El Paso's International Airport, Air National Guard at Minneapolis Airport, Chicago's O'Hare International Airport and Oklahoma City's Will Rogers World Airport.

  SchSCHMIDT International GmbH—SCHMIDT, located in St. Blasien, Germany, manufactures the AS 750 sweeper and also manufactures various types of vehicles for airport use, including sweeper-blowers, jet sweepers, front broom, spreaders with front spinners, sprayer-spreader, and runway cleaners. The AS 750 is designed for collecting ADF in the winter and airport debris at other times. The Triplex pickup system located at the rear of the vehicle consists of a combined suction and blower head and a hydraulically driven broom 15 inches in diameter and 80 inches long allowing a ADF collection width of 82 inches. An auxiliary engine drives the fan which produces a vacuum, the hydraulic pumps, and water pumps. The hopper has a tank capacity of 2113 gallons with a boom-mounted wander hose mounted to the hopper door.

  The AS 750 is known to be used in 22 countries, including: Germany, Belgium, China, CIS, Croatia, England, France, Hungary, Italy, Korea, Norway, Nigeria, Palestine, Poland, Portugal, Romania, Sweden, Slovenia, Spain, Thailand, U.A.E., and Vietnam.

3. Document whether reprocessing facilities are mobile or fixed installations or both and what accommodations are necessary for viable operations, such as electrical or other sources of power, access to sewer and water supplies, permits, licensing, etc.

Generally, it was found that the reprocessing facilities with daily processing capacities of greater than 20,000 gallons of ADF contaminated storm water were fixed installations. The skid-mounted reprocessing systems mounted on trailers process approximately 5000 gallons per day, but one installation can utilize up to four mobile systems. The ADF contaminated storm water is delivered to the reprocessing facilities either by tanker truck or via pipeline.

Power sources of 110v/60cy/1, 220v/60cy/3, and 440v/60cy/3 are needed to operate the installations. These reprocessing facilities generate effluent wastewater containing small amounts of glycol with the possibility of ADF additives. The reprocessing facilities in the U.S. and Europe are required to discharge their processed wastewater to a POTW from storage in a detention pond or tanks. Tap water is needed for utilities, maintenance and processing. These facilities must be designed to be within the NPDES permit limits set at each airport.

4. Describe, in general terms, the equipment and means employed for the removal of contaminants from spent ADF, which includes, but not limited to excess water, solid particulates, petroleum products, and original additives considered contaminants, such as polymers.

Reprocessing systems rely on a series of standard separation techniques to remove water and suspended solids and, in some cases, surfactants, corrosion inhibitors, and other additives from ADF-contaminated wastewater. Figure 1 shows the steps for purifying spent glycol for further processing which could include Type I ADF.

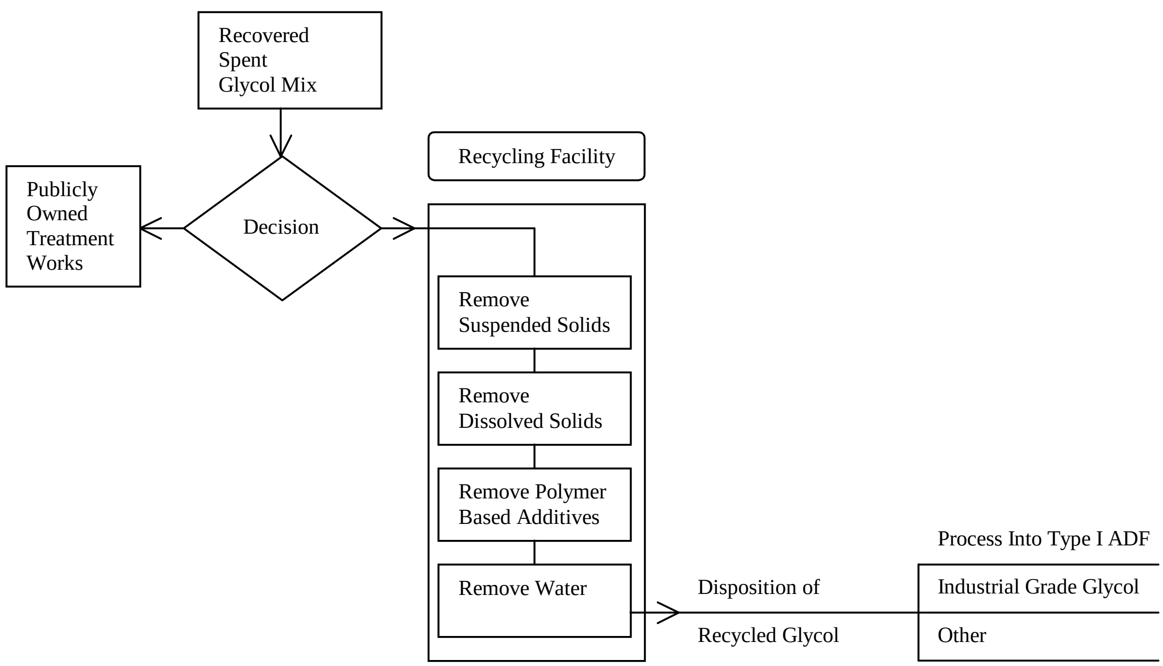

FIGURE 1. GENERALIZED FLOW DIAGRAM FOR PROCESSING OF SPENT GLYCOL

The typical glycol recycling system is operated as a batch process due to the variation in influent composition. The glycol recycling process generally consists of several steps, which may include filtration, ion exchange, nanofiltration, flocculation, reverse osmosis, evaporation, and distillation. Filtration is the first step in all glycol recycling systems because it removes suspended solids and prevents plugging of subsequent processing units. Once filtered, the wastewater may be passed through a series of ion-exchange columns to remove dissolved solids, such as chlorides and sulfates.

Nanofiltration and/or flocculation may be used to remove polymer-based additives, such as thickening agents, corrosion inhibitors, and surfactants. Water may be removed using distillation, evaporation, or reverse osmosis. Recycling systems that use distillation to remove water can produce products with glycol concentrations as high as 98 percent. Recycling systems that remove water using vapor recompression can result in glycol concentrations as high as 60% or those systems using reverse osmosis can get glycol concentrations as high as 10%.

5. Determine the criteria and success rate of obtaining a glycol base suitable for reprocessing into aircraft deicing/anti-icing fluids.

Airports involved in the recovery of spent ADF to be used in the recycling process strive to collect glycol wastewater with the highest possible glycol concentrations. Although ADF wastewater with glycol concentrations of 10% is preferable, most systems are capable of treating wastewater with glycol concentrations as low as 2.5%.

In situations where there are very low glycol concentrations, preconcentration techniques like reverse osmosis, can be used to increase the glycol concentrations prior to sending it to the distillation process which would have higher capital and operating costs.

There is state-of-the-art manufacturing technology available to obtain either an ethylene or propylene glycol base suitable for use in a Type I aircraft deicing/anti-icing fluid. Some reprocessing facilities are reducing the water content in the recycled glycol down to within 1% and 2%, while other facilities choose to reduce the water content down to 50% and 55%. Again stated, the reduction of water content is inversely proportional to the capital expenditure and operating cost.

6. If Item 5 results is a glycol base suitable for reprocessing into aircraft deicing/anti-icing fluids, describe the deciding factors in determining whether to sell to a fluid manufacture or on-site reprocessing of the glycol into certified deicing/anti-icing fluids.

When a glycol recycling facility is located within the airport boundary, it is generally more economical to reprocess the glycol base into a Type I aircraft deicing/anti-icing fluid. That is, provided that the recycler has a certified Type I formula or has the finances to certify a newly developed Type I fluid.

It is also imperative that the airlines using fluid at that airport have a agreement with the recycler to use the reprocessed Type I fluid.

Critical economic items for the on-site recycler to consider are transportation costs to the fluid manufacture and the liability insurance costs for the sale and use of aircraft deicing/anti-icing fluid.

Aircraft deicing/anti-icing fluid manufacturers, who must purchase the virgin glycol, have recently started business ventures with the recyclers of spent ADF to reformulate the aircraft grade recycled glycol into Type I aircraft deicing/anti-icing fluid.

7. If Item 5 does not result in a glycol suitable for reprocessing into aircraft deicing/anti-icing fluids, describe the available options, e.g., sale to businesses for processing into other products.

   At this time, most of the recycled ADF is sold to chemical blending operators and chemical manufacturers.

   Recycled ethylene glycol has limited industry use in coal antifreeze and for automotive antifreeze. Recycled propylene glycol has greater demand as an additive in paints, plastics, and various types of coatings.

   These products have applications in the current 98/2% solubility ratios and up to the 55/45 glycol/water ratio. The value of a recycled 50/50 ethylene glycol/water mix has been shown to be typically 30%-40% less than a similar 50/50 propylene glycol/water mix of the same volume.

   The disparity between ethylene and propylene glycol pricing has two factors: first, would be the range of industrial uses for propylene glycol is greater and than that of ethylene glycol. Secondly, the price of propylene glycol has a two-tiered cost structure. The selling price for industrial use is at a premium, whereas the selling price for use in the manufacture as an aircraft deicing/anti-icing fluid is substantially discounted by the raw material manufacturers.

8. Describe, in general terms, the equipment, means, and procedures by which reclaimed glycol is processed into aircraft deicing/anti-icing fluids (Types I, II, and IV).

   There are a variety of recycling and reformulating operators in the world. The reformulated end product is only a Type I deicing/anti-icing fluid. At this time, there are no Type II or Type IV being formulated from recycled glycol.

   In Germany, at the Munich Airport, Clariant Gmbh, a manufacturer of deicing/anti-icing fluids, operates a combination recycling plant and the reformulating plant. The Type I fluid produced is a propylene based 60/40 mixture. A 50% glycol concentration is the end product of the recycling process. As the fluid is transferred to a smaller batch tank, it is monitored, then a additive package is added to bring the fluid in the batch tank up to the AMS 1424 specification. Each smaller batch is tested prior to transferring the Type I fluid into the storage tank.

Appendix A, “Recycling of Aircraft Deicing and Anti-Icing Fluid—The Munich Way,” furnishes a complete description of the deicing operation, the collection system, and the recycling and reformulation process for Munich Airport.

In Canada and the United States, at several airports where Inland Technology Inc. has recycling plants, they are capable of recycling either ethylene or propylene glycol, but not at the same time at the same plant. The technology is based on mechanical vapor recompression (MVR) evaporation with proprietary add-on technology. This technology is incorporated into modular, portable concentrator systems having a throughput capacity of 2.1 million gallons per year operating at an on-line duty cycle of 90%. The equipment is skid mounted and can be operated either from a portable trailer or fixed facility. The typical recovered product is approximately a 50/50 mixture. The wastewater destined for the POTW contains approximately 0.5% glycol. Inland Technology has the technology to reformulate diluted glycol into a Type I fluid; however, due to the compliance issue regarding the test method for diluted fluids in AMS 1424C, these plants are not reformulating the recycled glycol into a approved Type I fluid.

In the United States, AR Plus Site Services Inc. manages recycling plants at the several airports and can process either propylene glycol or ethylene glycol, but not a mixture of both fluids. The typical recovered product is recycled into glycol/water mixture from 50/50 to 99/1. The recovered glycol is then sold to secondary markets. AR Plus also manages several Airport Stormwater sites where ADF has contaminated the stormwater during a deicing event. In the United States, The Environmental Quality Company (EQ) has their Michigan Recovery Systems Inc. (MRSI) facility located in Romulus, MI; it is equipped with a high efficiency evaporator and a batch distillation column for the processing of spent ADF. The facility recycles spent ADF received by truck from several Midwest airports including Detroit Metropolitan Airport (DTW) and the Pittsburgh International Airport (PIT). This facility is designed to recycle primarily propylene glycol based ADF wastewater. This facility produces a 99%propylene glycol product, it is marketed and sold as a virgin propylene glycol substitute to secondary markets.

EQ was responsible for the design and construction management of the recycling facilities at the Salt Lake City International Airport (SLC). The facility is very similar to MRSI in Michigan, with the notable exception that the distillation column is a continuous feed column that has the necessary stages to separate propylene glycol from ethylene glycol ADF wastewater. This system is designed to produce 99% propylene glycol and 99% ethylene glycol product. The evaporator is currently on line and the complete system is scheduled to be operational by September 2000. The recovered propylene and ethylene glycol is planned to be inserted into EQ’s existing glycol program and marketed as virgin quality substitutes.

From the PIT Airport a high concentrate spent ADF is transported to the MRSI facility for reclamation. The Airport is required to ensure that a “first flush” has occurred on their deicing pads prior to diverting the flow back into the storm water system. As a result, large volumes of low concentrate (typically 1-2% propylene glycol) spent ADF are generated. The local POTW is very small and can only allot 62.5 lbs. as chemical oxygen demand per day. The spent ADF wastewater had to be transported to a centralized wastewater treatment facility at considerable cost. Recently, EQ installed a low concentrated treatment system comprised of inclined plate clarification followed by ultrafiltration followed by reverse osmosis (RO). RO utilizes the difference in molecular size to selectively separate glycol molecules from water molecules. The RO system concentrates the glycol to approximately 10% and produces a permeate that has a chemical oxygen demand of approximately 200 mg/L. This system enables large volumes of clean permeate to be discharged to the local POTW. RO provides an excellent precursor to evaporation and distillation, because virtually any starting glycol concentration can be treated to produce a recoverable glycol/water stream while producing a permeate stream suitable for discharge.

In the United States, ADSI operates the recycling plant at the Denver Airport, can produce a 99% pure glycol and is capable of recycling propylene glycol, which is the only fluid used at this airport. The recycling system is operated as a continuous process and can process wastewater with a glycol concentrations as low as 1%. ADSI is responsible for marketing the recycled product to secondary markets.

The Denver airport incorporates a cascade collection system, where spent ADF is collected from specified full deicing pads. The spent ADF is drained directly to the recycling plant storage tanks. The next segregation of wastewater is generated in preparation of aircraft movement. This generally occurs at the gates and includes the deicing of landing gears, control surfaces, and engine cowlings. This wastewater is directed to a number of “dirty water” ponds and is forwarded to the local POTW under controlled pumped flow rates as a function of total tons of biological oxygen demand (BOD) pumped per day and the daily average per month.

9. Document the steps that have been employed to approve/certify an on-site reprocessing facility and whether the final product of the facility is aircraft grade glycol or deicing/anti-icing fluid. If the final product is deicing/anti-icing fluid, describe the steps employed to meet existing standards. If the final product is certified, what steps are taken to maintain a fluid consistent with its certification or must the certification be accomplished on a batch basis.

The inquires sent to the owners/operators of recycling and reformulation plants throughout the world proved that there are no approval or certification requirements for an on-site reprocessing facility. Permits for discharge of wastewater National Pollutant Discharge Elimination System (NPDES) are required; however, this pertains to the glycol concentration and pollutants contained in the effluent discharged to the POTW. This does not pertain to the facility and the process equipment. The storage tanks and related plumbing would be under the jurisdiction of Paragraph 5.0 (Fluid Storage and Handling) of SAE AMS 4737, titled Aircraft Deicing/Anti-Icing Methods with Fluids.

For an on-site reprocessing facility that reformulates the spent ADF, the only facility of this qualification is at the Munich Airport in Germany. To maintain a Type I fluid that is consistent with its certification, Clariant GmbH, the fluid manufacturer is the operator of the airport recycling facility and performs continuous batch tests. See appendix A, "Recycling of Aircraft Deicing and Anti-Icing Fluid—The Munich Way."

10. Document the success rate of deicing/anti-icing fluids, made from recycled glycol, successfully passing SAE AMS 1424, 1428, or other applicable certification standards and, if certified, how does the product compare to like products manufactured from virgin glycol regarding holdover time and other performance parameters in the above specifications.

Reformulated Type I aircraft deicing/anti-icing fluid was successfully processed and was used at several Scandanavian and European Airports through the 1999-2000 deicing season. The successful reformulated Type I fluids were tested to conform to the SAE AMS 1424 specification. A recent interpretation of the latest revision "C" of AMS-1424, by several airlines and cargo carriers, resulted in the current discontinued use of this reformulated fluid.

Typical plants that have had to discontinue the reformulation of Type I fluid are at Fornebu Airport, Norway and Lulea Airport, Sweden, and at Charles de Gualle Airport, France.

The recycling and reprocessing plant operated by Clariant GmbH at the Munich Airport in Germany is capable of reformulating an approved SAE AMS 1424 Type I fluid. Discussions with the Clairant Engineer at the Munich plant have confirmed that a 60/40 mixture of the Type I fluid produced has test results within the same range of values as the Type I fluid manufactured from virgin propylene glycol.

11. Compare, in general terms, the costs of collecting and recycling of spent glycols to the traditional methods of fluid disposal for an airport that has employed both methods, indicate if glycol recycling was motivated by environmental concerns alone or was cost savings also a factor.

The cost analysis for the collection and recycling of spent ADF is affected by several items including (1) the concentration of spent ADF collected, (2) the volume of the spent ADF collected, (3) the cost to collect the spent ADF from the pavement, (4) the transportation costs for to deliver the spent ADF to the recycling plant, (5) the capital cost of constructing or leasing a recycling plant, (6) the operating and maintenance costs of the recycling plant, (7) the cost for storage of the spent ADF, (8) the cost for storage of the recycled product, (9) the cost of leak detection systems, (10) the cost of recirculation systems to prevent the spent ADF wastewater from freezing, and (11) the revenue generated from the sale of the recycled product.

Typically the traditional method for most airports is to discharge the spent ADF contaminated wastewater to on-airport lagoons for metered discharge to publicly owned treatment facilities (POTWs). The cost factors involved with this method are: (1) the construction of detention ponds, (2) the transportation of the ADF wastewater to the ponds, (3) transportation of ADF contaminated waste water to the POTW, (4) the maintenance associated with operating the ponds, (5) aeration costs, and (6) annual POTW surcharges for wastewater treatment.

Typically, the airports that have invested in the collection and recycling of spent ADF, also must collect very low concentrations of spent ADF wastewater, not accepted by the recycling plant, into ponds for discharge to the POTWs.

Generally, a medium-sized airport located in the midwestern part of the U.S., may have these typical costs (all dollar amounts are based upon 1999 U.S. dollars) when recovering and recycling spent ADF:

Construction of recycling plant and storage tanks	≈ $3 to $5 million
Construction of deicing pads, drainage and detention ponds	≈ $20 to $25 million
Annual maintenance of detention ponds	≈ $100,000 to $300,000
Annual recycling plant maintenance and operating expenses	≈ $600,000 to $900,000
Glycol recovery vehicle (if needed/each)	≈ $80,000 to $250,000
Annual wastewater treatment charge from POTW	≈ $100,000 to $500,000

For the traditional method of using the wastewater ponds to collect all spent ADF and storm water for discharge to a POTW, the costs are generally:

Detention ponds with aeration	≈ $5 to $10 million
Annual maintenance of ponds and aeration equipment	≈ $300,000 to $1 million
Annual wastewater treatment charge from POTW	≈ $500,000 to $1 million
Annual wastewater transportation charges	≈ $400,000 to $900,000

Glycol recycling in the U.S. was not known to be performed prior to the EPA's publication of the storm water permit application regulations on November 16, 1990. Some European and Scandinavian airports were performing on-airport recycling as early as 1986 due to the storm water regulations in effect in countries like France, Norway, Sweden, Denmark, and Germany. In the U.S., following the 1990 regulations, the EPA identified the airports that were performing deicing/anti-icing operations. Based on the airport's aircraft deicing/anti-icing existing wastewater management systems, these airports were assigned to one of four wastewater management performance categories. Wastewater collections systems would include either on-site treatment or controlled discharge to a POTW. Cost saving or cost avoidance systems, like in recycling facilities, were then established to meet the requirement for on-site treatment of the glycol.

As an example, the Denver International Airport, incorporates the recycle of spent ADF as a matter of course of doing business. The original recycling facility, started its operations in 1995. Its design was based on the economics of resale of the fluid into the then undeveloped recycle market for propylene glycol. This limited the evaluation to the revenues associated with resale only. The integrated design resulted in a 10% feed concentration limitation on a multiple effect system. Feeds of less concentration have a significant effect on the production rate. With the growth of the airport operations, it was realized that the glycol collected in the retention dirty water ponds represented approximately the same mass of glycol now recovered at the recycling facility. It was also recognized that the avoided cost from sending the glycol as BOD to the POTW represented a revenue avoidance element that could be included in the overall cost evaluation. The result of the re-evaluation was the apparent capability to economically process fluids up to two orders of magnitude less concentrated, if proper equipment were in place.

As a result of a worldwide search by ADSI and the DIA Environmental Services personnel, a used stainless steel evaporator system had been located and purchased. The equipment and associated process are being upgraded for a large liquid throughput which will allow a major portion of the dirty water now being forwarded to the POTW to be used as a profitable feedstock. As the POTW charges increase with time and the value of the end uses of the recovered product relative to the virgin price increase, the process improvement will pay for further alterations. The end result is a strategic plan to avoid the cost and capability of the local POTW, the ability to provide a high-quality recycled product for resale or reuse, and offer the airport customers an improved airport service.

At several airports in the US, the driving force for recycling is the lack of organic loading available at the local POTW or the transportation costs to get the ADF wastewater to the POTW. In this situation, to reduce the organic loading to the POTW, the airport typically either transports spent ADF off the airport for recycling or disposal, or installs a treatment process at the airport. The ADF wastewater being discharged from the airport is closely monitored, generally by a hourly sampling.

The general term "recycling" is a treatment approach where glycol is separated and reused as opposed to aerobically or anaerobically degraded. Either way, there is a similar capital cost involved in the construction of these types of treatment processes, with the recycling approach providing an operational cost offset from the sale of glycol.

The cost impact for the discharge of spent ADF to the POTW cannot be disregarded unless the POTW is vastly overbuilt. Also, the cost of transporting the ADF to the POTW via pipeline or tanker truck varies considerably and should be considered.

In construction and maintenance amortization, two revenue streams that should be considered are POTW surcharge savings and the revenue generated from the sale of glycol. Typically the BOD Surcharge for ADF wastewater disposal will cost approximately $300 to $400 per ton.

If an airport collects a quantity of ADF wastewater to separate out 300,000 gallons of 98/2 Propylene Glycol/Water mixture, and the POTW has BOD surcharge of $0.15 per pound (approximately 1 pound of PG = 1 pound of BOD) the following calculations exist:

Glycol Revenue: 300,000 gallons × $2.40/gallon = $720,000

BOD Surcharge Savings: 300,000 gallons $\times$ 8.66 lb/gal (PG) = 2,598,000 pounds
2,598,000 lbs $\times$ \$0.20 per pound = \$519,600

ADF Wastewater transportation to POTW = \$350,000

Net Revenue = \$1,589,600

Typically, deicing pads are installed to improve winter operations and retention ponds are installed to environmentally control wastewater to the POTW. Once the airport has funded these projects, recycling can become a more attractive proposition.

12. Document unique, environmentally friendly methods that airports are employing for the disposal of spent glycol from aircraft deicing/anti-icing operations and if these methods are considered cost-effective.

Inquiries were sent to airports in Japan, Korea, China, several of the Scandanavian and European countries, in Russia and Poland, in addition to the U.S. One unique process was found at the Zurich airport. The process is to biologically treat the ADF wastewater. (See appendix B.)

4. REFERENCES.

1. "EPA Preliminary Data Summary, Airport Deicing Operations," January 2000, http://airportnet.org/depts/environmental/deicing.pdf.

5. RELATED DOCUMENTS.

1. "Funding Air Force Environmental Projects," US Air Force Fact Sheet (TI#16621), May 1998, http://ww.afcee.brooks.af.mil.

2. "Environment, Safety & Occupational Health (ESOH) Technical Planning Integrated Product Team (TPIPT) Need Assessment Summary, Need #1443," U.S. Air Combat Command, November 1997, http://xre22.brooks.af.mil/NASs/purpcont1443.htm.

3. "ESOH TPIPT Need Assessment Summary, Need: #914," Environmental Improvements to Aircraft Deicing Operations (ASC – 914), http://xre22.brooks.af.mil/NASs/purpcont 914.htm.

APPENDIX A—RECYCLING OF AIRCRAFT DEICING AND ANTI-ICING FLUID—THE MUNICH WAY*[*]

Remote Pads and Supply Stations

The demand that the main part of the consumption should be Type I fluid and a effective system for collection could be combined by using remote pads placed close to the runway.

The ten remote pads in Munich are divided into four deicing service areas (one at each runway head) with one service station at each area. These service stations are equipped with storage tanks for Type I and Type IV fluids, refill-taps for deicing vehicles, underground basin for used fluid, restroom and toilets for deicing crews, control system for pumps, tank-heating, and floodlights. The control of the collecting system is also performed from the stations.

Collecting System

The following two important facts had to be considered for the choice of system:

1. Effective collection of used aircraft deicing fluid (ADF) is only possible in areas dedicated to aircraft deicing were the influence of dilution due to precipitation can be kept at a financially acceptable level for recycling or disposal systems. Separate rules and procedures are necessary for the operation in these areas, including the handling of other fluids such as runway deicers and adapting snow removal techniques beneficial to the operation of the recycling system.

2. In order for the recycling system to process used ADF into certified ADF effectively, it is necessary to use fluid from the same manufacturer to avoid the “cocktail effect” in the end product. The “cocktail effect” can result by recycling products of multiple manufacturers. If the intent is to use the recycled fluid at the airport, to be economically feasible, that part of the used ADF Type I should be as high as the recycled rate (approximately 60% of the total consumption). A 60% recovery rate, with an efficient collecting system, is realistic. The current recycling technique only allows the manufacture of Type I fluid from a Type II or IV mixture.

All remote deicing pads at the Munich airport are drained to an underground collecting system. The collected fluid is first directed into a tank where the glycol concentration is measured with a

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density converter. The system monitors all fluids that come from the pads on a 24-hour-per-day basis. Fluids with a 5% glycol concentration or more are pumped to an underground basin (300 m³) for later transport to the recycling plant. Concentrations lower than 5% are pumped into the storm-water basin and then further to the local sewage plant. The system efficiently reduces the amount of rainwater/precipitation in the collected fluid, which is a key element in a cost-effective recycling system. The 5% "switch level" between recycling and not recycling is adjustable, but the 5% switch level was chosen due to local circumstances, including transport costs and acceptance by the local sewage plant.

Recycling Plant

The recycling plant facility in Munich is the center of operations for total fluid management of aircraft deicing fluid at the airport. In addition to the reprocessing system for aircraft deicing fluid, the recycling plant contains the main store for ADF, coordinates fluid transport, manages the ordering of virgin fluid and monitors the supply and collecting system.

The recycling system includes the following processing steps:

Mechanical Cleaning Step

The collected fluid is first mechanically filtrated by an ultrafiltration unit, where impurities such as sand, grass, oil, aircraft fuel Type IV thickener and other “dirt,” are removed. The unit has a capacity of approximately 4-5.000 L/h.

Chemical Cleaning Step

The next step in the process is chemical cleaning with an absorption and ionexchanger unit, anion and cation. The purpose is to remove heavy metals, chloride etc. A pH control of the fluid is also performed during this process. These steps result in a water and glycol mixture, which still contains excess water. The fluid is then pumped to buffer tanks before the distillation process. The unit capacity is approximately 7-8,000 L/h.

Distillation

The inlet concentration, to the distillation process, varies normally between 10% to 25% (with frost conditions or no precipitation, concentrations up to 45% have been measured). The vaporization is made by two distillation columns. The first operates with overpressure and a boiling point of approximately 120°C. (The boiling point for diethylene glycol is approximately 245°C and for propylene is glycol approximately 185°C.)

The second step operates with a vacuum and a boiling point of approximately 85°C. At full capacity, about 5000 L/h, water could be vaporized. The energy in the steam from step two is fed back to the district heating system at the airport. A heat exchanger recovers about 60% of the total energy consumption for the distillation process. The heat exchanger also creates the necessary vacuum for step two.

The glycol concentration in column two is constantly measured and when 50% glycol concentration (60/40 mixture) is achieved, the fluid is pumped to a batch-tank. The flow values by normal operation are:

Inlet:	approximately 8,000 L/h
Vaporized water:	approximately 5,000 L/h
Outlet (ADF 1):	approximately 3,000 L/h

During pumping to the batch-tank, an additive package is dosed into the fluid. This package is specially designed by the fluid manufacturer for this process and returns to the fluid the “missing links” so that all specifications for Aircraft Deicing Fluid (ADF), Type I, are fullfilled.

When one batch-tank, 43 m³, is produced, the process switches automatically to the next batch-tank. A quality control check on the produced batch is performed and the results are sent to the fluid manufacturer for approval. (One liter from each production batch is retained for 1 year in the plant and 0.1 liter is sent to the fluid manufacturer for backup control.)

If a test sample is disapproved, the batch system assures a minimum of reprocessing of 43 m^3 at most. Normally, the monitoring system provides an alarm and corrects the process automatically before large volumes are incorrectly produced. (Disapproved charges are pumped back to the collecting tank and processed from the beginning once again.)

The fluid that is produced in the plant is a ready to use 60/40 mixture. The deicing operator has decided only to use this concentration at the airport. As a result, the recycling process is more cost efficient since the total water content does not have to be vaporized. If required, virgin Type I fluid is also diluted down to this mixture before being supplied to the service stations at the remote pads.

Fluid Quality

The task in the planning of an ADF recycling plant included the ability to produce a fluid that fulfills all specifications for ADF and have full acceptance by the airlines. At an early stage, it was realized that this could only be accomplished jointly with a fluid manufacturer. Therefore, the fluid manufacturer was involved in the project from the onset. The fluid manufacturer had to establish all quality demands for the plant in order to accept the quality and take responsibility for the final product.

Neither the deicing operator nor the airport are able to maintain the quality control; therefore, the operation of the recycling plant in Munich is to be carried out by the fluid supplier. The fluid manufacturer for Munich is Clariant GmbH, and they are now responsible for the total operation of the plant. The fluid that is produced in the recycling plant meets the same specification as other products from Clariant GmbH. This assures that the fluid is produced with the same quality control as in the manufacturer's plant and the final fluid could be used with the same product information sheet, (safety sheets, operational instructions, etc.) as for standard products.

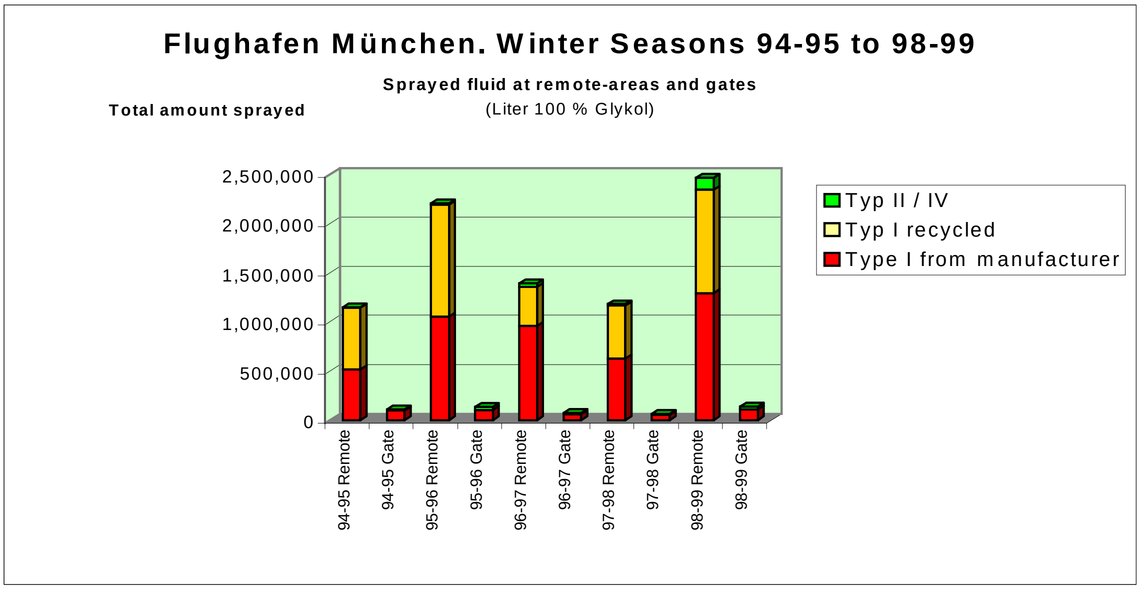
One of the main advantages of this system is that the product liability insurance is carried by the manufacture. Any problems with licenses or patents for the product are avoided, and the fluid supplier is always on site to support the deicing operator or questions from the airlines.

To fulfill all quality requirements from the fluid manufacturer, the entire recycling system is supervised by several measuring and control points. Samples of the fluid are taken for analysis in the laboratory and the results are certified and documented. Samples (1 liter) from all production batches and from truck-batches leaving the plant are retained in the plant for 1 year. With this system in place, it is possible to follow the fluid throughout the system.

The fluid produced in the recycling plant meets the specification according to AMS 1424.

Recovery Rates

Since the start-up of the plant in 1992, about 50% of the total consumption of ADF Type I has been fluid from the recycling plant. Due to high capacity and good quality management with the glycol supplier, Clariant GmbH, the collected fluid is put back into operation within a few days. With the new ultrafiltration system, installed in the winter of 99-00, the processing of both types of fluid is now possible (used Type IV will be reprocessed into Type I fluid) and the loss, depending upon the extent that Type IV is mix with Type I, could be reduced to a minimum. The total recovery rate is expected to increase.



The diagram shows that the remote system reduces the use of Type IV fluid. The number of deicing operations that have taken place at positions where runoff could not be controlled in a proper way, as at the gates, have been reduced to a minimum.

The recycling system is a very important part of the total environmental protection system at Munich Airport. In addition, due to lower costs for recycled fluid, the recycling system reduces the total cost for the deicing operator.

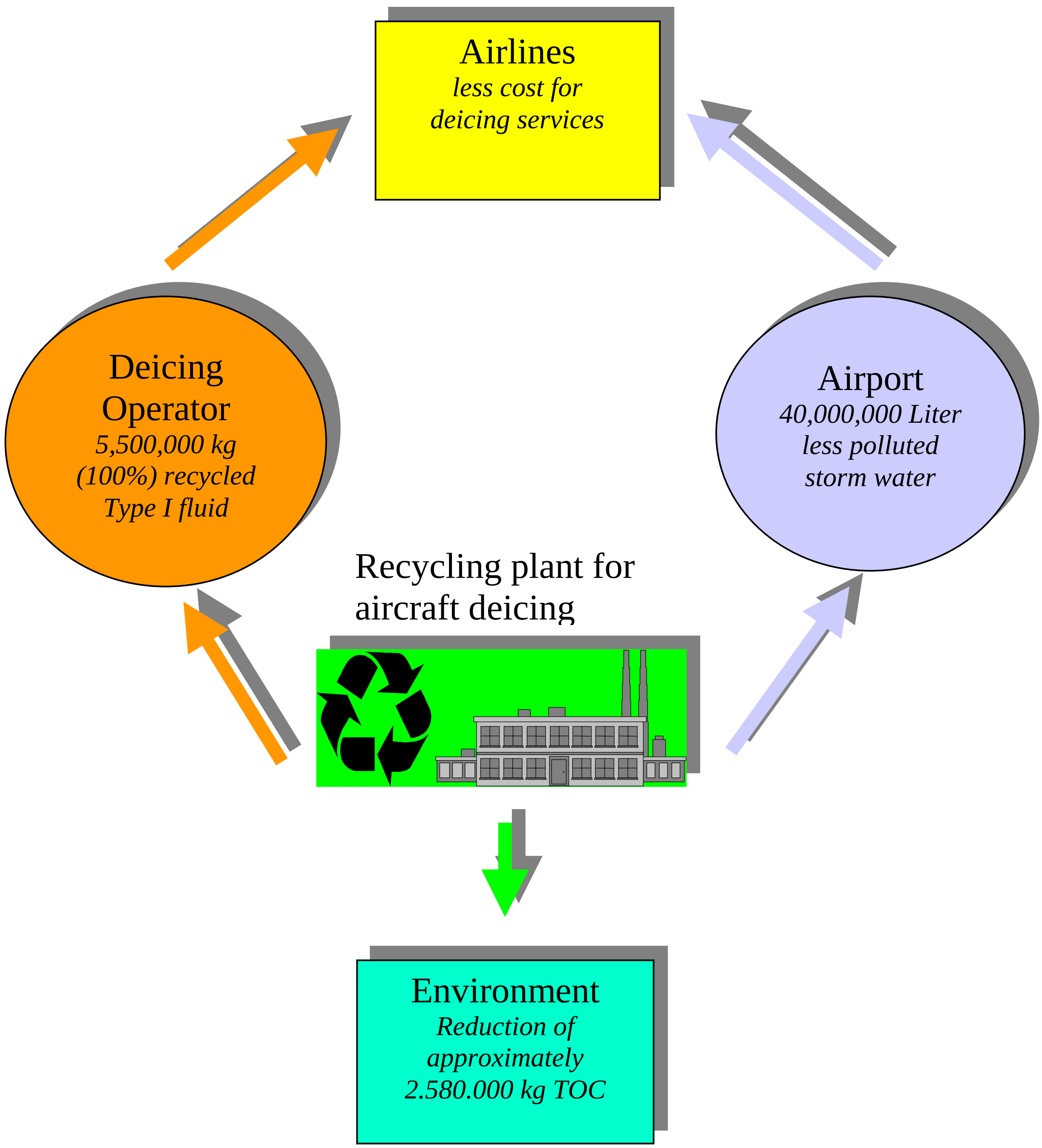
Pertinent Facts:

- Since the opening of the Munich airport in 1992, about **10,000,000 liters of recycled ready to use ADF Type I (60/40)** has been produced and sprayed.

- Due to the recycling system, approximately **40,000,000 liters** less glycol polluted storm water was released to a local sewage plant.

- The total reduction of TOC released to the sewage system is approximately **2,580,000 kg**

Balance for the Winter Seasons 92-93 to 99-00



Facts and Figures of Recycling Plant

Storage Capacity

Collecting basin, underground for used fluid:	400 m^3
Collecting tank, for used fluid:	350 m^3
Tank, prefiltered fluid:	350 m^3
Tanks, cleaned fluid:	150 m^3
Tank, distilled water, (from the process):	50 m^3
Batch-tank 1, “ready to use” fluid 60/40:	50 m^3
Batch-tank 2, “ready to use” fluid 60/40:	50 m^3
Storage line 1, “ready to use” fluid 60/40:	250 m^3
Storage line 2, “ready to use” fluid 60/40:	250 m^3
Tanks, virgin fluid:	100 m^3
Tank, wastewater:	50 m^3
Tank, additive concentrate:	10 m^3
Tank, HCl:	7 m^3
Tank, NaOH:	7 m^3
Tank, Oil:	50 m^3

Process Capacity

Cleaning:	4 - 5.000L/h.
Distillation:	5.000 L /h. (vaporization)

Operation example Distillation, inlet glycol concentration at about 20% – 25%:

Inlet:	8.000 L /h.
Distillate:	5.000 L /h.
Outlet (ADF I):	3.000 L /h. (60/40, +85°C)

Facts Deicing Stations/Collecting System

Deicing Station (26L) Storage capacity: Type I: 70 m³ (60/40 at +85°C) Type IV: 23 m³ Collecting basin, underground: 300 m³ Deicing pads: DA1, 11.200 m²: Gantry DA2, 6.750 m²: Deicing vehicles DA3, 6.750 m²: Deicing vehicles	Deicing Station (26R) Storage capacity: Type I: 46 m³ (60/40 at +85°C) Type IV: 23 m³ Collecting basin, underground: 300 m³ Deicing pads: DA1, 11.100 m²: Deicing vehicles DA2, 6.700 m²: Deicing vehicles
Deicing Station (08R) Storage capacity: Type I: 46 m³ (60/40 at +85°C) Type IV: 23 m³ Collecting basin, underground: 300 m³ Deicing pads: DA1, 12,000 m²: Deicing vehicles DA2, 8,700 m²: Deicing vehicles	Deicing Station (08L) Storage capacity: Type I: 70 m³ (60/40 at +85°C) Type IV: 23 m³ Collecting basin, underground: 300 m³ Deicing pads: DA1, 11,200 m²: Deicing vehicles DA2, 6,600 m²: Deicing vehicles DA3, 5,800 m²: Deicing vehicles

Transport Capacity

3 tanks at 25,000 liters for supplying the remote pads with "ready to use fluid"

2 tanks at 25,000 liters for collected fluid from the remote basins to the recycling-plant

3 trucks

Collecting System for Storm Water and Low Concentrated Fluid

Underground basin:	58,000,000 liters
Open basin 1:	16,000,000 liters
Open basin 2:	46,000,000 liters
Total:	120,000,000 liters

Zurich Airport

Treatment of De-icing Sewage at Zurich Airport

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Airport Authority Flughafen Zürich

Zurich Airport

Treatment of De-icing Sewage at Zurich Airport

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1. Background

Winter service for aviation safety

The airport authority is responsible for winter safety. To maintain safety in aviation, chemicals are used at Zurich airport to de-ice aircraft and aircraft operating areas in winter and under certain weather conditions.

De-icing the apron (approx. 102 ha) as well as runways and taxiways (approx. 88 ha) is in the competence of the airport authority. The operating surfaces are kept mechanically clear of snow and ice. In case de-icing is required, lower alcohols like ethylenic glycol and isopropanol or, under harsh conditions like freezing rain or for safety reasons, urea is used. Due to this composition of chemicals the only substances affecting water are organic carbon and nitrogen compounds.

De-icing of aircraft is undertaken by the companies SR Technics and Jet Aviation during the winter period which is usually from beginning of November until the end of March. At present up to 270 aircraft are de-iced daily at all stands in the open as well as at the finger docks. The substance used for de-icing is ADF2 (e.g. Kilfrost ABC3) and ADF4 with a longer holdover time.

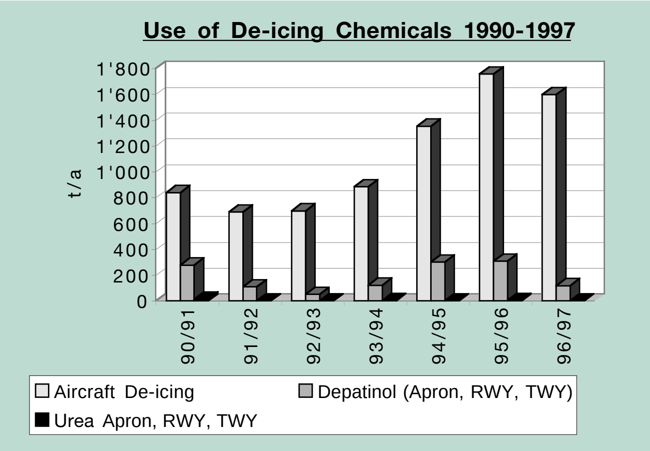

Fig 1: Use of de-icing chemicals

Direct dumping into the main ditch without previous treatment

The most important surface waterway in the vicinity of the airport is the river Glatt, which flows to the North along the Western airport boundary. The average flow of water in the river amounts to approx. 6 m^3/s. Approximately 20% of the water originates from discharges of sewage-treatment plants along the river. The quality of the Glatt was clearly improved during the last years.

The substances used to de-ice aircraft and aircraft operating areas enter the Glatt by way of the drainage system. However, only 40% of the de-icing substances enter the main ditch, the remainder of the de-icing fluids evaporates or is dispersed into the surrounding fields where it decomposes. Due to temporary fluctuations in the use of chemicals, there are certain times of the year in which the Glatt has to cope with peak loads. In consequence, during the six winter months, strong bacterial growth, mud deposits, depletion of oxygen as well as a higher concentration of ammonium and DOC may be found in the main ditch.

The amount of sewage calculated for an average winter period of 135 days and total rainfall of 300 mm is 295,000 m^3/winter from the apron and 500,000 m3/winter from the runways and taxiways.

To dump the sewage into the main ditch the following cantonal limits have to be met:

Total undissolved substances:	20 mg/l
BOD_5:	10 mg O_2/l
DOC:	20 mg C/l
Ammonium-N + Ammoniac-N	2 mg N/l[1] 4 mg N/l[2]
Nitrit-Nitrogen:	0.3 mg N/l
Total Phosphor :	0.8 mg P/l
[1] warmer seasons [2] colder seasons	(24 hours average)

After a series of comprehensive tests and studies made between 1985 and 1987 a project based on a conventional sewage plant was developed (bacterial growth in mud deposits). Due to mainly financial reasons it could not be realised. The unsatisfactory situation continued.

2. Pilot project: The root bed sewage plant

Reed ponds as a close to nature process

The task force "De-icing" (Zurich Airport Authority, department of water protection and hydraulic engineering and Swissair) thus decided in 1993 based on ecological and economical reasons for a root bed sewage plant as a close to nature solution.

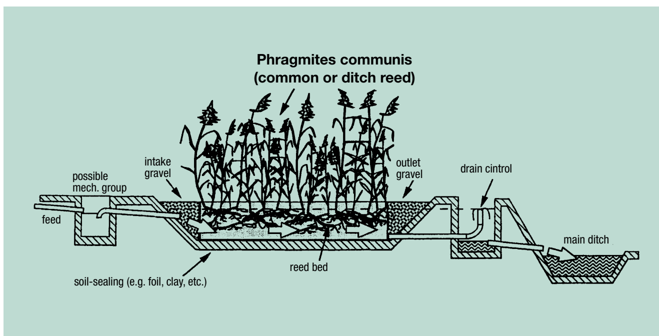

Fig. 2: Working principle of the root bed sewage plant

The eco-technical procedure uses a physical, chemical and biological active soil and is based on the ability of microorganisms to decompose organic substances. The proper composition of the soil guarantees the successful functioning of the plant. Reeds are planted in the soil so that the oxygen required for decomposing is led through the dense system of roots. Together with the direction of the sewage flow, this allows for aerobe and anaerobe structures which lead to decontamination in the soil partitions that are completely saturated with sewage effluent.

Preliminary tests in spring-summer 1993 with de-icing sewage proved the efficiency of the cleaning procedure. Therefore a pilot plant of 5,000m³ was planned in autumn 1993 and built in summer 1994. Four basins of 3x1200 m² and 1x1800 m² with different feeds (vertical, horizontal and diagonal seeping currents) were built.

Special procedures were required to build the plant West of the taxiway November, which meant that special skills had to be demanded from the construction workers. The four basins were all sealed with waterproof sheetings and filled with a mixture of humus and brick gravel based on a ground analysis, before being planted with reeds (density: 5 plants per square meter - a total of 27,000 plants). Finally 2-3 cm bark compost was distributed over the entire surface. In order that the soil mixture was not tread on while levelling and planting (risk of compressing the soil), the construction firm built a special bridge from which levelling and planting was conducted.

The necessary de-icing sewage for the pilot plant was taken from the apron drainage of the terminals A and B with 47 docks and about 54 ha operating areas and fed into the mixing plant at the maintenance facility. The mixing plant also served as a dosage system because it can store concentrated de-icing sewage to be discharged in appropriate concentrations in the times of the year de-icing fluids are not used. The quantity of sewage fed into the plant depends on the program being run and varies between 4,5 and 17 m³/d, the load amounting to between 18 and 100 kg COD/d. The sewage enters the first reed basin through a delivery pipe (preclarification with vertical feed and partial overdamming) or the distributer, from

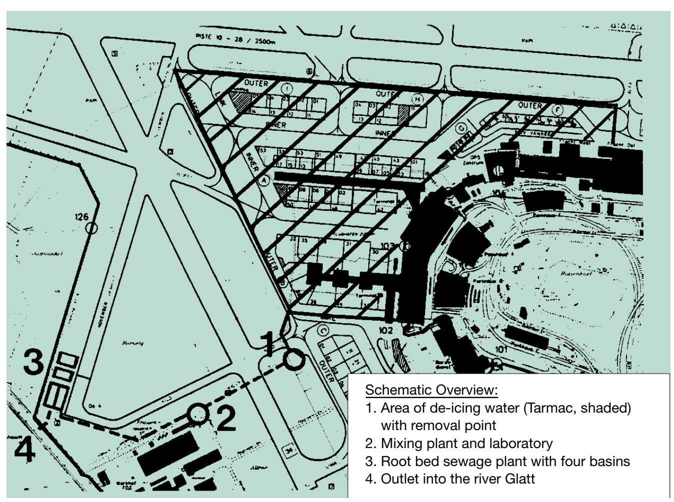

Fig 3: Schematic Overview

where it is fed parallel into the other three separate basins.

Positive results

During the pilot phase the plant was operated by the Airport Authority maintenance team as instructed by the process engineer. The department of water protection was closely involved during the trial period.

In the first operating year 1994-1995, due to the complex and up to now little known construction a few defects and damages had to be repaired. At the same time various changes had to be carried out (e.g. the controls). Therefore only single results were available that first year. From winter 1995, however, the trial programs could be run as planned and completed in summer 1997.

With a surface of 5,000 m^2, the plant could treat loads of 1,710 mg DOC/l during a few winter months and 3,140 mg DOC/l in summer below the limit. The annual purifying capacity was 32 g COD/m^2. There was still a cleaning of the sewage in winter time. During a four week nonstop freezing period the reed bed sewage plant kept a cleaning performance of 99%. Other weather influences like thawing or heavy rain didn't affect the performance much. The overall configuration would result to a vertically fed pre-treatment step with an integrated retention pond and a horizontally fed treatement step.

During the pilot phase further important knowledge was gained concerning the process and operation:

- The construction is very delicate and needs greatest attention because of the difficulty to repair damages like in the water insulation.
- Under certain circumstances there is the danger of short circuits and then the sewage flows away from the surface unpurified.
- According to the feeding program, temporary odour problems occur.
- The maintenance of the plant is basically more expensive than expected.
- In warmer seasons the retention of sewage can be problematic.
- The bird strikes are no problem.

Conclusion

The root bed sewage plant is a suitable nature-like procedure to purify de-icing sewage and can comply with the given limits if properly fed.

The overall concept following the pilot project intends to use a first stage for the storage (close to 50,000 m^3) and pre-treatment. In a second treatment stage there will also be a storage capacity of 15,000 m^3. As a result the sewage can constantly flow throughout the year into the Glatt while complying with the legal limits. The plant needs an operating area of 6.5 ha.

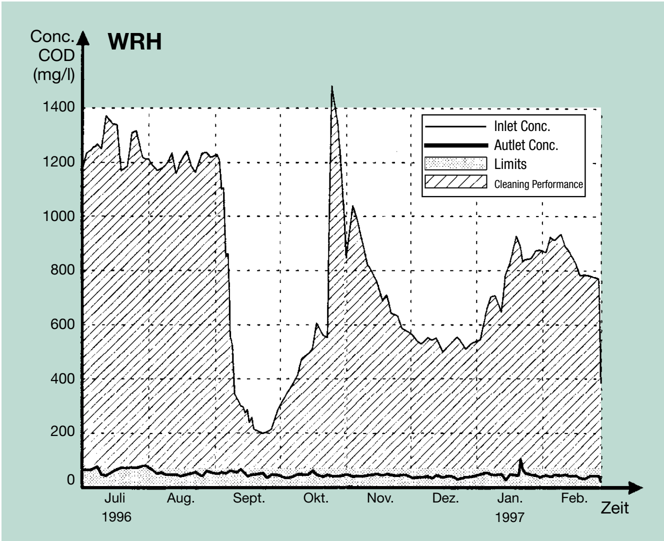

Fig. 4: Example for the degradation of COD

3. Alternatives

Within the 5th building phase of the airport Zurich, the cleaning of the de-icing sewage is an important project. The realization was laid down within the framework concession of the federal government. Due to the developments achieved in sewage treatment systems it was considered advisable to take up other promising options and evaluate them in spite of the current pilot project. For the prequalification, four additional cleaning procedures were chosen for further consideration which included a test phase:

- Spray irrigation
- Structured soil bed with aeration
- Solid bed reactor
- Sewage plant Werdhölzli (city of Zurich)

3.1. Spray irrigation

The idea is based on the knowledge that already today about 50% of the used de-icing fluids from aircraft are sprayed on the surrounding area without leaving any residues in the ground or drainage water. The planned system makes use of this phenomenon.
The whole de-iceing sewage is sprayed by an irrigation system on suitable surfaces within the airport area. The decomposition of the pollutants occurs in a natural way through the microbiological activitiy in the top 60-90 cm of the soil filter. The decomposition is mostly aerobic. A preconnected retention pond of 4,000 m^3 guarantees a controlled distribution. The purified de-icing sewage flows into the river via the drainage system. With an irrigation surface of 20 ha the discharging limits can be met. This procedure is close to nature and inexpensive.

3.2. Structured soil with aeration

The procedure “aquaplant” is a close to nature cleaning system, which functions with plants grown in a structured soil bed. This system can additionally be aeriated. The sequentially switched basins can be run in circles, which guarantees to reach the discharge values. First the sewage is stored in 3 basins according to the concentration with a total of 14,300 m^3 (with a limit of 2,500 mg C/l). The cleaning plant consists of two treatment lines with 5 cascade forming basins each. The soil filter in the basin is composed of lava or gravel and special biologically highly active substances. The planting with reeds or reed mace serves mainly the maintenance of the soil structure.

3.3 Solid bed reactor

The “BIOPUR”-system is a three-stage plant consisting of dammed up, rerinsing solid bed reactors with a bio-film in which the pollutants are decomposed. The sewage is directly pumped into the plant according to amount and concentration over a TOC-online measurement or into the four overflow basins with a total volume of 9,500 m^3. With an intelligent storage management and recycling possibilities, a rather continuous flow over the biology can be achieved.

The pilot plant could purify the de-icing sewage below the limits without problems. Impact loads were no problem. On average the load of 1,700 $\text{mg/l}_{\text{reaction volume}}$*day could be treated. The plant has a short adaption time (about 12 days

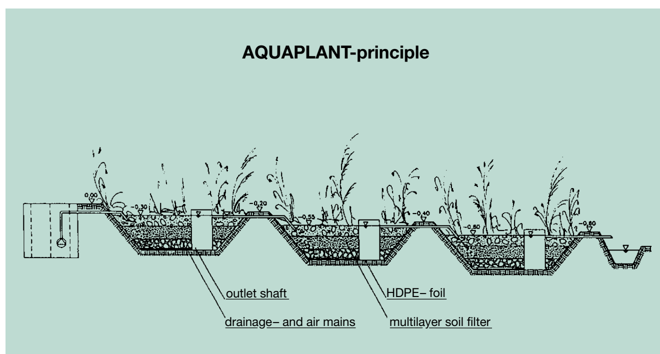

Fig 5: Principle of Aquaplant

Depending on the specific de-icing mission, a considerable lapse of time must be expected until the sewage is purified and can be discharged into the river. The procedure is rather meant for a continuous flow of water with lower concentrations.

when started up) and can adapt quickly to changing concentrations. Longarmed bacteria caused a problem, which seemed almost resistant to draining and caused the danger of plugging. A mixing with other sewage or a changed support

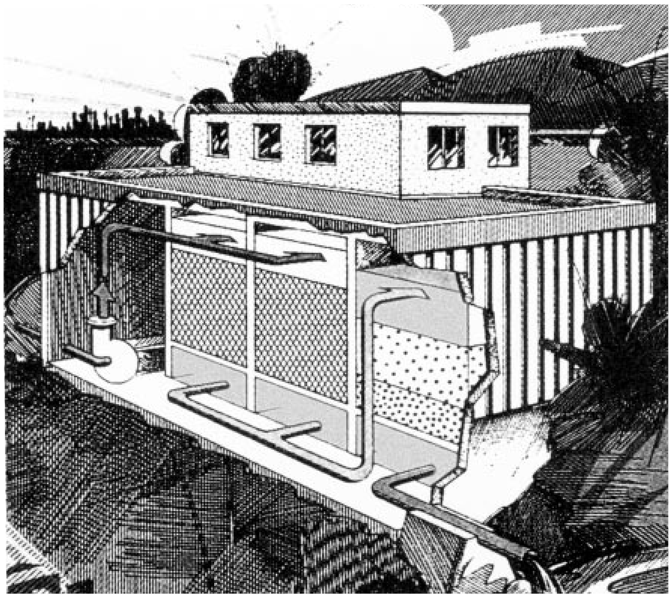

Fig 6: BIOPUR treatment plant

biology could help out. The system is relatively energy and surveillance intensive and expensive compared to other close to nature alternatives.

3.4. Sewage plant Werdhölzli

The communal sewage plant Kloten-Opfikon, to which the Airport is connected hasn't the hydraulic and waste capacity to absorb also the de-icing sewage. However, the sewage plant Werdhölzli (city of Zurich) has still enough capacity. The de-icing sewage would flow through a pressure pipe of 4 km into the Glattal tunnel and mixes there with the household sewage and is then dumped into the plant Werdhölzli. It serves there as an easily utilized carbon source for denitrification.

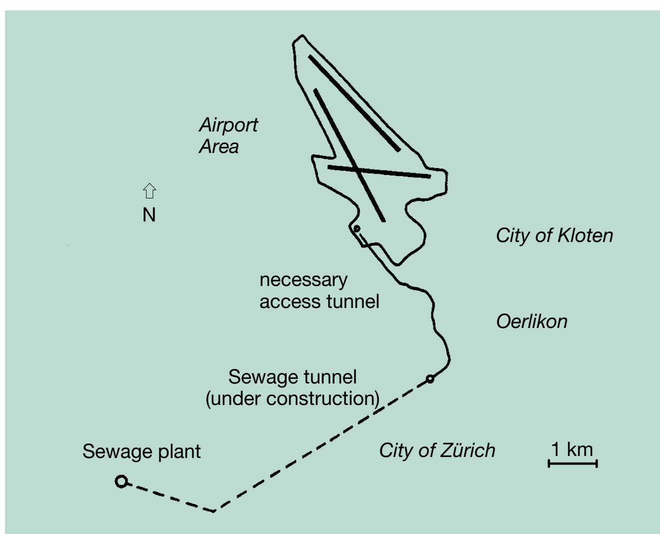

Fig 7: Plan with sewage tunnel

For optimum operation, 3 stacks of basins of each 2,000 m³ volume are necessary. The maximum allowed carbon-load to the sewage plant is 150 kg C/h during the week and 250 kg C/h at weekends. The denitrification capacity can then be increased up to 57%.

This method means the lowest internal cost for the airport of Zurich, even if a certain political dependence is accepted.

4. Evaluation

All five procedures in discussion were tested in detail, evaluated and compared with each other.
The top priority was the legal compliance. Further factors were the process stability, safe disposal, close to nature and after all investment and operation costs. In principle all procedures meet the required limits.

Root bed sewage plant

Through the conception of the plant with an integrated storage capacity and a distribution of loads throughout the year, this procedure shows a high stability. The efficient functioning of this system depends strongly on the starting conditions and demands a high maintenance effort.

Spray Irrigation

The sprayed sewage is decomposed in the soil filter to values below the limits. Although spraying must be optimized to actual airport conditions, the ecological objections are marginal. In favour of this procedure are the lowest investment and operation cost.

Structured soil with aeriation

The Aquaplant procedure is based mainly on continuous quantities of water with low concentrations. Besides a large stack volume the system needs a long time until the de-icing sewage is purified.

Solid bed reactor

The Biopur-plant is capable to decompose the loads of de-icing sewage to the required limits by mixing it with normal sewage. High investment and operating cost are to be expected.

Sewage plant Werdhölzli

The disposal of the de-icing sewage in the Werdhölzli plant is a contribution to the optimizing of the consisting sewage plant, especially the denitrification process. This method is under political reservation, a practical solution for the airport with little internal effort.

5. Decision and further procedures

Spray irrigation as close to nature solution

On account of studies and field tests this close to nature and inexpensive method of spray irrigation was chosen.
This procedure has a long tradition in sewage cleaning, however due to the need for large areas it is hardly represented in Switzerland.

Development

On account of the monitoring results and according to a high-value procedure a necessary irrigation area of 20 ha was designated. This means an average irrigation of 340 mm de-icing sewage per winter.

The resulting de-icing sewage is sprayed by irrigation systems on suitable surfaces within the airport area. To guarantee a controlled irrigation, a stack volume of 5,000 m^3 is planned, distributed over several decentralized units according to specific locations. Special attention must be given to the distribution plant so that the system does not freeze during long periods of frost.

Fieldtests

In the winter 1996/97 experiments were made and during two months de-icing fluid was irrigated on selected surfaces. An extensive monitoring program ensured that enough data are available for the judgement. Analysed were:

- Ground water
- Drainage Water
- Soil
- Snow cover

With an intermittent irrigation in the second month, hydraulic short circuits could be avoided even though they could not be excluded. The alcohol analyses of the soil samples showed that in all test fields the starting substances were almost fully decomposed. Even two months after completion of the tests there was no increase in the DOC concentration.

The de-icing irrigation quantity should not be scaled on a fixed unchangeable area of irrigation fields but should be operated in a way that hourly, daily or total loads brought to the fields do not exceed a safe load. The standard dimensional criteria is the carbon and not the hydraulic load.

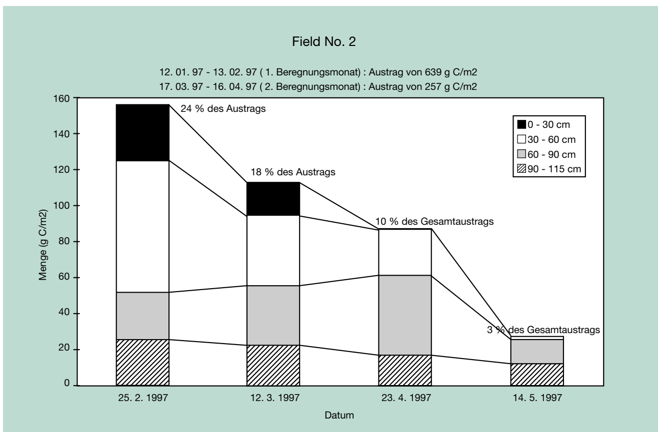

Fig 8: Carbon in the test field no 2.

A serie of special questions was analysed during the tests.

- Addition of nutrients:
  The irrigation does not fertilize like liquid manure. Even though an increase in nitrogen can contribute to a better decomposition, it's possible to do without addition of nutrients during the first years of operation.
- Colmation: Closing of the soil pores could not be observed.
- During trial periods no indication of drenching or flooding of the soil occured.
- The bird behavior was not conspicuous.
- The results of the monitoring excluded the danger of sprayed sewage flowing off from a snow and ice cover.
- Air measurements showed no evaporation of the alcohol and therefore additional VOC-emissions.

Conclusions

The principle of a close to nature procedure to purify de-icing sewage has been confirmed.
The use of the spray irrigation method has several advantages:

- Legal compliance.
- Very close to nature procedure, low use of energy intensive technology.
- Little need of actual operating area, the irrigation fields are already existing green areas.
- Extensifying process is not affected.

- The realization is possible within the airport area.
- Quick realization
- Low investment and operating costs.

Root bed sewage plant as a further component

The reed bed plant is still operated. Various possibilities are in discussion, amoung them:

- Pretreatment of de-icing sewage for breaking of peak concentrations.
- Cleaning of apron sewage from the new apron stands West (summer and winter).

According to the further use certain modifications must be made to the existing plant.

To guarantee the safe disposal if problems should occur later with the chosen procedure, the sewage plant Werdhölzli is still negotiated with as a backup solution.

Further actions

The department of water protection and hydraulic engineering (since January of 1998 department of waste, water, energy and air) has confirmed that the procedure of spray irrigation can be permitted under various conditions. Within the scope of the 5th extension stage a concession project with environmental impact study is worked out and submitted to the relevant authority (Federal Office for Civil Aviation) for approval.

With the realization of this plant for purifying the de-icing sewage, Zurich Airport gets rid of not only an unsatisfactory situation but also tries to make further use of close to nature procedures in environmental protection.